The USNO Rubidium Fountain

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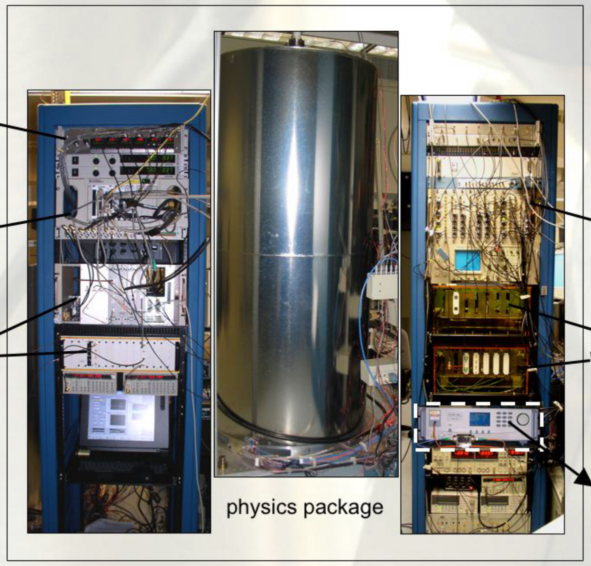
http://tycho.usno.navy.mil/clockdev/CDpapers.html

Abstract

The U.S. Naval Observatory plans to incorporate rubidium atomic fountains in its clock ensemble to improve the performance of the Master Clock. We have built an engineering prototype with short-term performance of $1.4\times10^{-13}/\sqrt{\tau}$ and have started medium- and long-term characterization of the device.

Overview

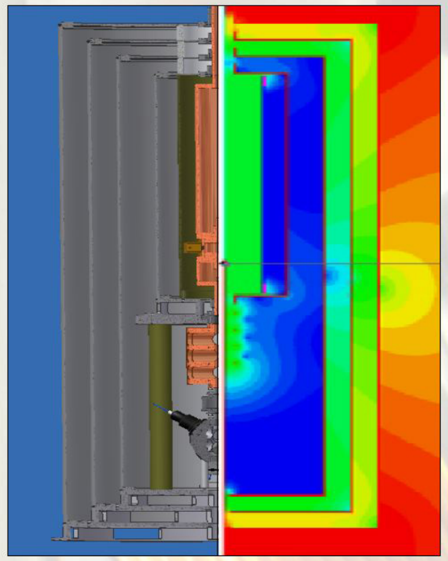
Our fountains need to run in an operational environment without user intervention. Toward this end we have developed a compact, robust system that will be contained in three equipment racks.



USNO Rb atomic fountain

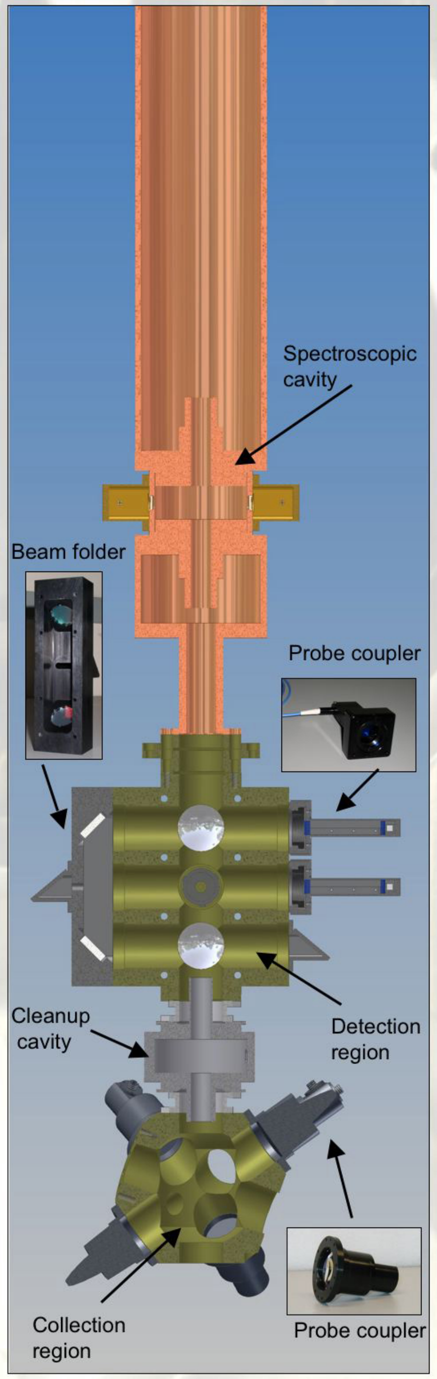
Design

Magnetic Shields



The physics package is entirely enclosed within magnetic shields. Three layers of magnetic shields cover for the collection region, and a fourth covers the drift region. The shields are designed for operation from molasses without the need for magnetic bias coils.

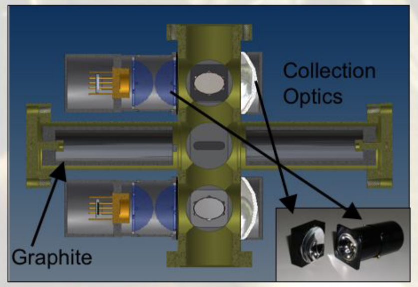
Physics Package



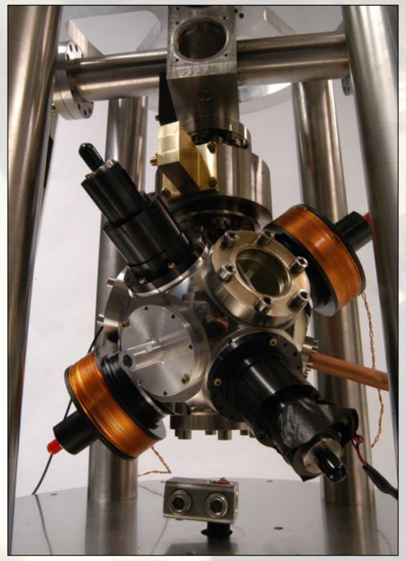
Rb atomic fountain vacuum chamber cross section with monolithic couplers for delivering laser beams.

The physics package consists of machined titanium vacuum chambers with weld-in windows. Monolithic couplers which bolt directly to the vacuum chamber deliver the required collection/launching, detection and probe laser beams. All components are nonmagnetic.

Rb atoms (~10^8 atoms in MOT or 5×10^6 in molasses) are collected, cooled and launched with a velocity of 4m/s every 1.2 s from the collection region. A moving-frame molasses duration of 1.6 ms and adiabatic beam turnoff of 0.2 ms cools the atoms to ~1.5 μK. A cleanup microwave cavity and laser beams in the detection chamber prepare the atoms in the $|2,0\rangle$ state for Ramsey spectroscopy. As the atoms fall back down, collection optics (F/0.64 lenses and spherical mirror) capture the light scattered by returning atoms.



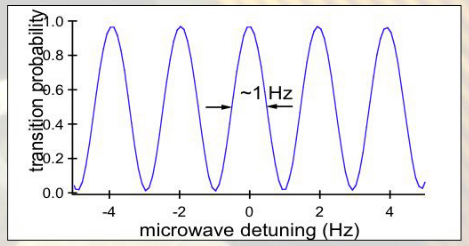
Detection region, side view.

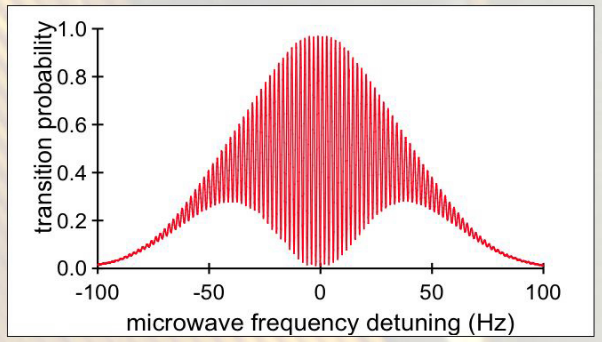


Collection Region

Performance

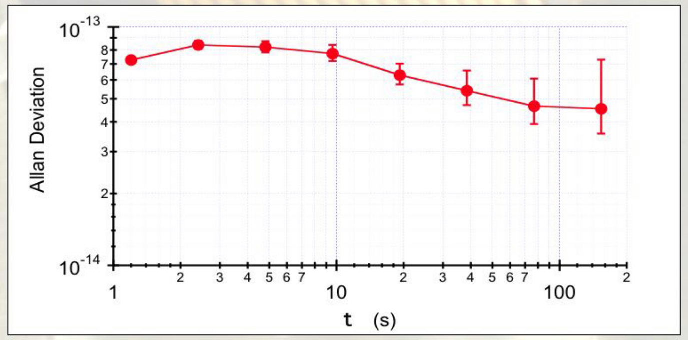
Ramsey Spectroscopy

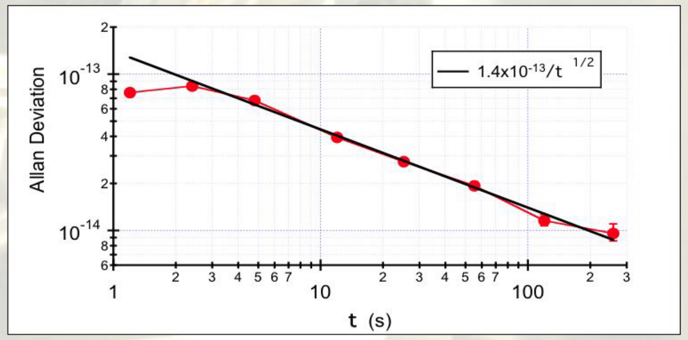




Stability

The stability of the fountain when our reference crystal is not steered to a maser is below 1×10^{-13}.





Current best short-term stability of the fountain versus a maser is $1.4\times10^{-13}/\sqrt{\tau}$.

After one day of averaging, the fountain performance is comparable to an active hydrogen maser. We are investigating longer runs to better evaluate the fountain's stability at longer averaging times.